# Candidate Cool-Season Legumes for Filling Forage Deficit Periods in the Southern Great Plains

S. C. Rao,* B. K. Northup, and H. S. Mayeux

## ABSTRACT

This study was conducted to determine seasonal forage production and nutritive value of the cool-season annual legumes grasspea (*Lathyrus sativus* L. cv. AC-Greenfix) and lentil (*Lens culinaris* Med. cv. Indianhead) grown to fill the spring forage deficit period of the southern Great Plains. Data were collected from March to June in 2001 through 2003 at the USDA-ARS Grazinglands Research Laboratory, El Reno, OK. Seeds of each species was inoculated and planted (60-cm row spacing) annually on 15 March (75 kg ha$^{-1}$ for grasspea; 25 kg ha$^{-1}$ for lentil) in 60-m$^{-2}$ plots. Aboveground biomass was collected on five dates [45–95 d after seeding (DAS)], dried 60 h at 60 to 65°C, weighed, and used to calculate aboveground standing crop. Samples were ground (1.0 mm) and analyzed for nitrogen (N) and in vitro digestible dry matter (IVDDM) concentrations. Standing crop and N concentration showed significant ($P = 0.05$) interactions between DAS, cultivars and years. Differences were detected for DAS $\times$ cultivar and DAS $\times$ year interactions for IVDDM concentration ($P = 0.05$). Grasspea outperformed lentil and reached its maximum yield of 6415 vs. 2013 kg ha$^{-1}$, respectively, on 75 DAS before declining. Nitrogen concentration (23–55 g kg$^{-1}$) and IVDDM (786 $\pm$ 3 g kg$^{-1}$) of the two cultivars were similar during the growing season. The higher level of production gives grasspea greater potential as a component of wheat-based (*Triticum aestivum* L.) forage systems in the southern Great Plains, particularly for filling the deficit period during late spring.

T HE PRIMARY GOALS of grazing-based forage systems are to provide year-round high-quality forage and reduce the use of expensive stored forage or purchased feeds. In the southern Great Plains, winter wheat and such warm-season perennial grasses as bermudagrass (*Cynodon dactylon* L.), and Old World bluestem (*Bothriochloa* spp.), are the primary forage resources for livestock production (Phillips and Coleman, 1995: Coleman and Forbes, 1998; Krenzer, 2000). Wheat pasture is available for grazing from November to mid March if a grain crop is harvested, or through late April to early May if grain is not harvested (Redmon et al., 1995; Krenzer, 2000). The warm-season grasses are available for grazing from June through September, although quality is limited during the last two months. Therefore, the standard grazing system used in the southern Great Plains has voids during two critical times of the year. One occurs in the fall (September to November), when quality and production of the warm-season perennial grasses are low and winter wheat is not yet available for grazing.

The second occurs in late spring and early summer (May to June) when wheat has ceased growth and warm-season pastures are not yet available for grazing (Northup, 2003). New plant species that can fill these gaps with dependable high quality forage are needed to support sustainable forage-livestock production systems in the region.

Recent research in the northern Great Plains has focused on partially replacing summer fallow with annual legumes for ground cover, green manure, or forage (Badaruddin and Meyer, 1989a, 1989b; Biederbeck et al., 1993). Little research has been conducted on potential candidates for green manure or grazing in the southern Great Plains. Among the grain legumes, grasspea, also known as chickling vetch, and lentil have been noted for their tolerance to dry conditions and adaptability to difficult environments (Nygaard and Hawtin, 1981; Biederbeck et al., 1993; Campbell, 1997).

Grasspea is a grain legume grown on the Indian subcontinent, southern Europe, and northern Africa for forage and grain production for both livestock and human consumption (Chowdhury, 1988). This crop has significant potential for the southern Great Plains because of its tolerance to stress (Palmer et al., 1989). Despite a high level of drought tolerance, it is not greatly affected by excessive rainfall and can be grown on flood-prone land (Kaul et al., 1986; Rathod, 1989). Grasspea is well adapted to cool-season production in warm-temperate and subtropical areas such as Africa and western Asia. It is widely grown in these regions for its high yield potential and high-quality forage, as an alternative to fallow periods in cropping systems (Osman and Nersoyan, 1986). Gowda and Kaul (1982) reported forage yields of 7 to 10 Mg ha$^{-1}$ in Bangladesh when interseeded with maize (*Zea mays* L).

Over the past decade, this species has received increased attention as a multi-use crop in arid regions of the northern Great Plains (Biederbeck et al., 1993; Biederbeck and Bouman, 1994). In parts of this region, grasspea yields of 5000 kg ha$^{-1}$ with 30% crude protein have been reported (Raloff, 2000). However, more extensive use of this grain has been limited by presence of the neurotoxin β-N-oxalyl-L-α, β-diaminopropionic acid (ODAP) in older accessions. There have been no reported cases of Lathyrism in ruminant species, as some groups of microbes in the foregut utilize the amino acid components of the neurotoxin (Rasmussen et al., 1992). Plant breeders have concentrated on developing low-ODAP cultivars and the variety 'AC-Greenfix' was released by the Semi-Arid Agricultural Research Center at Swift Current, SK, Canada.

Lentil is an important crop in the rainfed farming systems of the Mediterranean-like environments of western Asia and northern Africa. The grain is a valuable source

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USDA-ARS, Grazinglands Research Lab., 7207 W. Cheyenne St., El Reno, OK 73036. Received 7 Jan. 2005. *Corresponding author (srao@grl.ars.usda.gov).

of protein in human diets of the region, and the straw is valued as livestock feed (Nygaard and Hawtin, 1981). In the Middle East, North Africa, Ethiopia, and India, lentil residues are important in farming systems as a feed for livestock (Muehlbauer et al., 1995). Before the 1970s, lentil production was almost nonexistent in North America, but it has since become an important crop in the semiarid plains of Canada and the northern USA. Most of the hectares planted to lentils in North America occur in North Dakota, Montana, eastern Washington, northern Idaho, and western Canada.

Recent research on annual legumes as cover or green manure crops in the northern Great Plains has included lentil as a partial replacement for summer fallow periods (Badaruddin and Meyer, 1989a, 1989b; Biederbeck et al., 1993). McPhee et al. (1997) reported that six lentil cultivars grown in Pullman, WA, produced 1400 to 3300 kg ha$^{-1}$ of residues, and lentils produced 4300 kg ha$^{-1}$ biomass under rainfed conditions in Syria (Oweis et al., 2004). Lentil is able to derive a significant amount of N by $N_2$ fixation and sustain rates of fixation through pod fill. Kessel (1994) reported that daily rates of N accumulation were 3.82 kg N ha$^{-1}$ d$^{-1}$, and at maturity N accumulation was 149 kg ha$^{-1}$.

Information pertaining to forage production and forage quality of lentil and grasspea in the southern Great Plains is limited. The objectives of this study were to determine the seasonal patterns of forage production and nutritive value of grasspea and lentil in the central region of the southern Great Plains.

## MATERIALS AND METHODS

### Study Area and Experimental Design

This study was conducted from 2001 to 2003 at the USDA-ARS Grazinglands Research Laboratory near El Reno, OK (35′ N, 98°0′ W, elevation 414 m) on a Dale silt loam (fine-silty, mixed, superactive, thermic, pachic Haplustolls) soil. Average maximum and minimum temperatures during the March through June growing period are 25 and 16°C, respectively. Long-term (1978 through 2003) average precipitation during the growing period was 432 mm.

The cultivars used were AC-Greenfix grasspea and Indianhead lentil. Experimental plots (3 by 20 m) were disked and 60 kg ha$^{-1}$ $P_2O_5$ was applied during the first week of March in each year. No N fertilizer was applied. Cultivars were repeatedly planted on the same plots throughout the study. Seeds of each cultivar were treated with a commercial liquid inoculum of *Rhizobium leguminosarum* (Lipho Tech Inc., Milwaukee, WI)[1] and seeded in 60-cm rows at 75 kg ha$^{-1}$ (75% germination) for grasspea and 25 kg ha$^{-1}$ (85% germination) for lentil on 15 March each year. Seeding rates and row spacing provided approximately 15 to 20 plants/m row. Efforts were made to maintain consistent planting and sampling dates. Rainfall and ambient temperature at the site were monitored throughout the study period.

Aboveground whole plant samples were collected on five sampling dates from 45 to 95 DAS. Three randomly selected

0.5-m lengths of rows were clipped 2.5 cm above ground from each plot, and samples were collected at a new location on each sampling date. Plant samples were dried in a forced-draft oven at 60 to 65°C to a consistent weight and used to calculate aboveground standing crop. Samples were then ground to pass a 1.0-mm screen and analyzed for N concentration using a complete combustion N analyzer (Leco CHN-1000, Leco Corp., St. Joseph, MI)[1]. In vitro digestible dry matter was determined by the two-stage technique of Tilley and Terry (1963), as modified by Monson et al. (1969).

### Statistical Analyses

Nitrogen concentration, IVDDM and aboveground standing crop were analyzed as repeated measures within a randomized block ($n = 3$) design with a split plot in time (Steel and Torrie, 1980). Blocks and cultivars ($n = 2$) represented the main plots, years ($n = 3$) the split-plot, and DAS the repeated element ($n = 5$). Multivariate and univariate tests were applied in all analyses (Statsoft Inc., 1995), and Mauchley's test for compound sphericity was used to define the validity of univariate analyses in determining DAS effects (Crowder and Hand, 1990; Johnson and Wichern, 1990). Correlation matrices were also examined to define the influence of individual DAS on other dates within analyses. In cases where compound sphericity did not exist (e.g., distribution of observations in an analysis was not normal due to autocorrelation among DAS), analyses were restricted to multivariate analyses [Wilk's Lambda ($\lambda$) and Roy's Greatest Root] and Greenhouse-Geiger adjusted univariate tests (Crowder and Hand, 1990). Trends in responses were determined with the polynomial contrast subroutine. Mean contrasts in significant effects were tested by Bonferonni's *t*- test (Statsoft Inc., 1995). Level of significance for all tests was set at $P = 0.05$.

## RESULTS AND DISCUSSION

### Environmental Conditions

The amount and distribution of precipitation during the study period varied among years (Table 1). Total precipitation in 2001, 2002, and 2003 was 63, 56, and 51%, respectively, of the long-term 25-yr average. Most of the precipitation received in 2001 was in May (73%), whereas 41% of 2002 and 2003 precipitation was received in April and June, respectively. Growing conditions could be described as moderate droughts during all three years of the study. Ambient temperatures during all three years deviated by $\pm$ 2°C or less from the site averages (USDA-NRCS, 1999).

### Tests of Sphericity

Mauchley's test of compound sphericity indicated that aboveground standing crop data were not normally dis-

**Table 1. Precipitation recorded at the study site during the 2001 through 2003 growing seasons (March–June).**

| Month | Years | | | |
|---|---|---|---|---|
| | 2001 | 2002 | 2003 | 25-yr average |
| | mm | | | |
| March | 25 | 37 | 33 | 72 |
| April | 14 | 99 | 32 | 73 |
| May | 199 | 46 | 66 | 102 |
| June | 34 | 59 | 91 | 125 |
| Total | 272 | 241 | 222 | 432 |

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[1] Mention of trademark, propriety product, or vendor does not constitute a guarantee or warranty of the product by USDA and does not imply its approval to the exclusion of other products that may be suitable.

**Table 2. Tests of compound sphericity on responses of two annual cool-season legumes to the effect of days after seeding.**

| Variable | Mauchley's $W$ | $\chi^2$ | df | $P$ |
|---|---|---|---|---|
| Standing crop | <0.01 | 22.5 | 9 | 0.01 |
| Nitrogen concentration | 0.02 | 9.7 | 9 | 0.38 |
| Dry matter disappearance | <0.01 | 11.9 | 9 | 0.22 |

tributed (Table 2), and autocorrelation was present between DAS. As with Mauchley's criterion, the correlation matrix describing interdependence indicated large influences among DAS in aboveground standing crop. Large levels of interdependence were noted among 45, 55, and 65 DAS ($r = 0.73$ to $0.86$) and among 65, 75, and 95 DAS ($r = 0.85$ to $0.93$), indicating standing crop recorded on DAS early and late in the study were partially interrelated. Such responses are not unusual. Biomass accumulates with length of season so standing crop recorded at an earlier date will have some degree of correlation with standing crop at later dates (Crowder and Hand, 1990).

In contrast, Mauchley's test indicated that N concentration and IVDDM data had approximately normal distributions (Table 2), and that univariate tests were not influenced by DAS effects. The correlation matrix testing interdependence among DAS effects on N concentration found minimal influences among dates. Some autocorrelation was noted between 55 and 65 DAS ($r = 0.56$), but was not enough to nullify the univariate analysis. The correlation matrix of interdependence among DAS effects on IVDDM also showed little autocorrelation between dates. The largest amounts were noted between 65, 75, and 95 DAS ($r = 0.39$–$0.54$). On the basis of results of Mauchley's test criterion and the correlation matrices, tests applied to aboveground standing crop were restricted to multivariate analysis of variance and adjusted univariate tests, and results should be considered with caution (Johnson and Wichern, 1990). Univariate analyses of variance were applied to N concentration and IVDDM.

## Analyses of Variance

Multivariate analysis of variance showed differences ($P = 0.05$) DAS, and DAS $\times$ cultivar $\times$ year interaction effects on aboveground standing crop (Table 3). Greenhouse-Geiger adjusted univariate tests agreed with results of the multivariate analysis. The overall trend in

DAS effect was a cubic increase with maxima recorded on 75 and 95 DAS, but the relationship was not consistent across cultivars and years (Fig. 1). The highest standing crop was recorded for grasspea on 75 DAS of 2001 (7763 kg ha$^{-1}$), and a group with similar levels were noted on 95 DAS in 2001, 75, and 95 DAS in 2002, and 65, 75, and 95 DAS in 2003. The lowest standing crop was produced by lentil on 45, and 55 DAS of all years (65, 227, and 277 kg ha$^{-1}$ in 2001, 2002, and 2003) and by grasspea on 45 DAS in 2001, and 2002 (258 and 387 kg ha$^{-1}$).

Standing crop responses suggest that environmental conditions, especially timing and amount of precipitation, influenced cultivar performance. Biomass production was highest in 2001 and could be attributed to above-normal precipitation, and growing season precipitation, in May 2001. The flatter response at the end of the 2002 growing season appeared to be related to lower amounts of precipitation during May and June, compared with 2001 and 2003. Cultivar differences were similar to those noted by Biederbeck et al. (1993) during a 6-yr study in southern Canada, with grasspea producing significantly more standing crop than lentil. However, grasspea produced an average of only 312 kg ha$^{-1}$ more forage in that environment. Mean growing season precipitation during their study was 148 ($\pm$52) mm, compared with 245 ($\pm$25) mm in our study. Further, evapotranspiration rates in Oklahoma is greater because of prolonged high temperatures than in Canada. Average end-of-season (95 DAS) standing crop of grasspea in our study was 3775 ($\pm$245) kg ha$^{-1}$ greater than, or 2.5 to 3.8 times, the production of lentil. This may also be due to lower plant density.

Larger yield from lentil may not be possible because of its growth form. Lentil plants are typically short with slender stems and produce small amounts of biomass relative to grasspea, which has decumbent stems up to 1 m long. Forage yield by lentil was similar to values reported in the Pacific Northwest of the USA and southern Canada (Kusmenoglu and Muehlbauer, 1998; Biederbeck and Bouman, 1994). Lentil production has been reported as somewhat limited by drought conditions. Silim et al. (1993) and Oweis et al. (2004) reported that lentil yield can be increased by 5 to 15 fold with supplemental irrigation. Forage production by lentil was

**Table 3. Repeated measures multivariate analysis of variance (MANOVA) of aboveground standing crop of two annual cool-season legumes.**

| | Wilk's $\lambda$ | | | | | Roy's greatest root | | | | | Greenhouse-Geiser† | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | df‡ | | | | | df‡ | | | | | Univariate | | | Adj df | | |
| Source | S | E | Value | $F$ | $P$ | S | E | Value | $F$ | $P$ | df | MS | $\varepsilon$ | 1 | 2 | $P$ |
| Date | 4 | 1 | 0.01 | 10 161 | <0.01 | 4 | 1 | 40 642 | 10 160 | <0.01 | 4 | $4.7 \times 10^7$ | 0.33 | 1.3 | 4.2 | <0.01 |
| Error $a$ | | | | | | | | | | | 8 | $2.8 \times 10^5$ | | | | |
| Date $\times$ cultivar | 4 | 1 | 0.01 | 2 450 | 0.02 | 4 | 1 | 9 798 | 2 450 | 0.02 | 4 | $1.2 \times 10^7$ | 0.33 | 1.3 | 4.2 | <0.01 |
| Error $b$ | | | | | | | | | | | 8 | $1.6 \times 10^5$ | | | | |
| Date $\times$ year | 8 | 2 | 0.01 | 262 | 0.01 | 4 | 2 | 8 594 | 8 594 | <0.01 | 8 | $1.1 \times 10^6$ | 0.33 | 2.7 | 5.3 | 0.01 |
| Error $c$ | | | | | | | | | | | 16 | $1.4 \times 10^5$ | | | | |
| Date $\times$ cultivar $\times$ year | 8 | 2 | 0.01 | 212 | 0.01 | 4 | 2 | 23 729 | 23 729 | <0.01 | 8 | $8.5 \times 10^5$ | 0.33 | 2.7 | 5.3 | <0.01 |
| Error | | | | | | | | | | | 16 | $4.1 \times 10^4$ | | | | |

† Greenhouse-Geiser adjusted univariate ANOVA test; adjusted degrees of freedom (Adj df) are approximations.
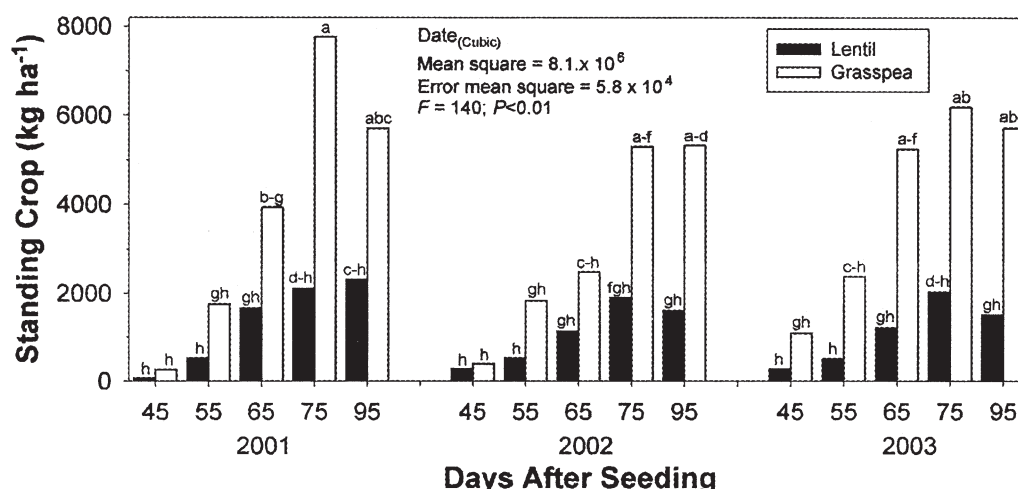‡ S and E are degrees of freedom for source of effect and error terms, respectively.

**Fig. 1. Mean aboveground standing crop of two annual cool-season legumes at different days after seeding (DAS) during 2001 through 2003. Bars with the same letter were not significantly ($P > 0.05$) different.**

shown to increase by 32% under irrigation in Syria, compared with rainfed conditions (Oweis et al., 2004).

No differences were noted between cultivar or year (main) effects in N concentration or IVDDM (Table 4). Effects of DAS were significant, as were interactions between DAS, cultivars, and years for both N concentration and IVDDM. The overall trend in DAS effect on N concentration was a quadratic decrease, but it was not consistent among cultivars or years (Fig. 2). For example, responses of lentil in 2002 and 2003 were cubic. The highest N concentration was recorded for grasspea on 45 DAS of 2001 (56.3 g kg$^{-1}$). Nitrogen concentration of lentil was also greatest (50.4 g kg$^{-1}$) on 45 DAS of 2001. The lowest N concentrations were recorded during the last two dates of 2002 and 2003. Nitrogen concentration on the first two sampling dates was slightly greater for grasspea but these differences usually disappeared at later sampling dates.

A cultivar $\times$ year interaction was noted in IVDDM across all DAS (Table 4). Effects related to DAS were also significant, as were two-way interactions between DAS and cultivars and DAS and years. Digestible dry matter was similar among cultivars in 2001 (787 and

785 g kg$^{-1}$), while IVDDM was 5% higher in grasspea during 2002 and 5% higher in lentils during 2003 (Fig. 3). When averaged across years (Fig. 4A), IVDDM of lentil and grasspea was similar during the first two sampling dates (871 vs. 872 g kg$^{-1}$ and 829 vs. 832 g kg$^{-1}$ on 45 and 55 DAS, respectively). Digestible dry matter diverged thereafter, with lentils more digestible on 65 DAS (780 vs. 745 g kg$^{-1}$) and no differences thereafter. In date $\times$ year interactions (Fig. 4B), the greatest amount of IVDDM averaged across cultivars was recorded on 45 DAS of 2001 (902 g kg$^{-1}$) and declined over time, with no differences among years for any given date except 95 DAS. The overall trend in DAS effect on IVDDM was a cubic decline, but the relationship was not consistent across cultivars or years, as noted in the quadratic responses of lentil across years and responses across cultivars in 2001.

Grasspea was significantly ($P = 0.05$) more productive than lentil. At peak standing crop (75 DAS), grasspea produced an average of 6415 kg ha$^{-1}$ of forage with an average N concentration of 26.2 g kg$^{-1}$. Grasspea effectively contained 168 kg ha$^{-1}$ of total N in aboveground growth as a green manure. In contrast, lentil pro-

**Table 4. Repeated measures univariate analyses of variance of N concentration and in vitro digestible dry matter (IVDDM) of two annual cool-season legumes.**

| Source | df | N Concentration | | | IVDDM | | |
|---|---|---|---|---|---|---|---|
| | | MS | F | P | MS | F | P |
| **Within DAS effects** | | | | | | | |
| Intercept | 1 | 106 239 | 4275.9 | <0.01 | 54 031 500 | 12 951.0 | <0.01 |
| Block (B) | 2 | 22 | 0.1 | 0.98 | 68 | 0.1 | 0.98 |
| Cultivar (C) | 1 | 214 | 11.3 | 0.18 | 116 | 0.3 | 0.91 |
| Error a (B × C) | 2 | 19 | | | 519 | | |
| Year (Y) | 2 | 62 | 2.5 | 0.23 | 3 901 | 9.3 | 0.23 |
| C × Y | 2 | 142 | 5.7 | 0.06 | 10 603 | 25.4 | 0.01 |
| Error b (B × Y) | 8 | 25 | | | 417 | | |
| **Between DAS effects** | | | | | | | |
| Date (D) | 4 | 1 720 | 74.8 | <0.01 | 103 787 | 402.3 | <0.01 |
| Error c (B × D) | 8 | 23 | | | 258 | | |
| D × C | 4 | 64 | 4.3 | 0.04 | 1 492 | 4.9 | 0.03 |
| Error d (B × D × C) | 8 | 15 | | | 304 | | |
| D × Y | 8 | 61 | 4.7 | <0.01 | 1 757 | 6.6 | <0.01 |
| Error e (B × D × Y) | 16 | 13 | | | 266 | | |
| D × C × Y | 8 | 30 | 3.0 | 0.03 | 846 | 2.3 | 0.07 |
| Error | 16 | 10 | | | 363 | | |
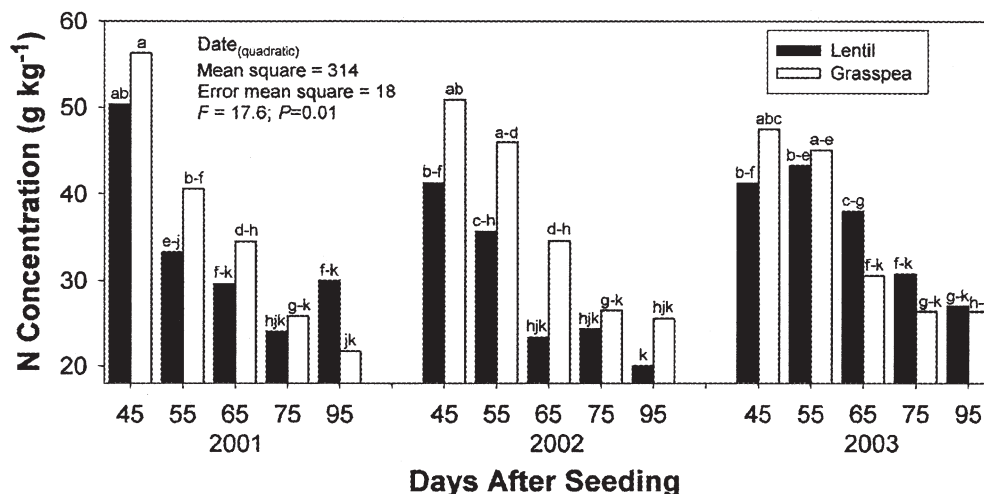
**Fig. 2.** Mean N concentration of two annual cool-season legumes at different days after seeding (DAS) during 2001 through 2003. Bars with the same letter were not significantly ($P > 0.05$) different.

duced an average of 2013 kg ha$^{-1}$ above ground growth at peak standing crop with 26.3 g kg$^{-1}$ N, which equated to 53 kg N ha$^{-1}$. As a green manure, N fixed by grasspea could be used to meet a larger fraction of the N requirements for a following crop of forage wheat (108 kg ha$^{-1}$) than lentil.

## Implications

Lentil and grasspea appear to be well adapted to the southern Great Plains, and both produced biomass that could be used for grazing or as a green source of N. Similar results in studies in southern Canada (Biederbeck et al., 1993) indicate that both cultivars could function as forages or green manures across a wide latitude of the Great Plains. Despite the occurrence of three consecutive years with below-normal precipitation, both cultivars were capable of producing forage. Use of water-efficient cultivars in forage production systems is important in the southern Great Plains, where amount and timing of precipitation are variable (Northup et al., 2002), and the reliability of regional forecasts for planning agricultural activities are uncertain (Schneider

and Garbrecht, 2003). While both cultivars did produce biomass during our study, grasspea produced greater amounts than lentil. This higher level of production under drought conditions may be partially related to water-use efficiency. Biederbeck and Bouman (1994) recorded 18% greater efficiency in water use by grasspea compared with lentil.

The dry conditions encountered during this study limit the scope of inference that can be generated from the results. Responses of these cultivars to growing conditions during normal or wet years cannot be addressed, nor is it clear that grasspea would out-produce lentil under average or higher precipitation. There is little information on responses of these cultivars to moisture regimes and nothing available for the Great Plains.
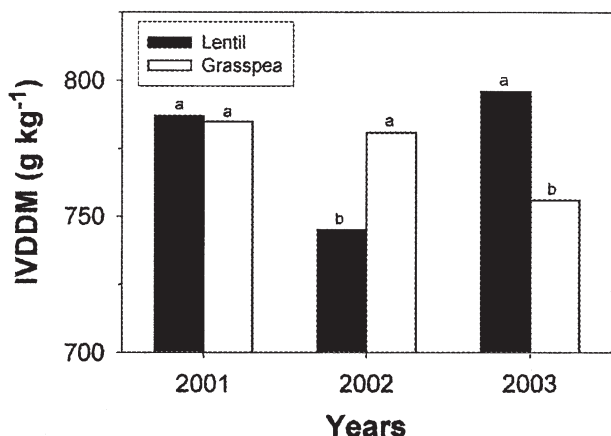


**Fig. 4.** Mean in vitro digestible dry matter (IVDDM) of two annual cool-season legumes by days after seeding, averaged across years (A) and across cultivars (B). Bars with the same letter were not significantly ($P > 0.05$) different.



**Fig. 3.** Mean in vitro digestible dry matter (IVDDM) of two annual cool-season legumes during 2001 through 2003, averaged across days after seeding. Bars with the same letter were not significantly different ($P > 0.05$).
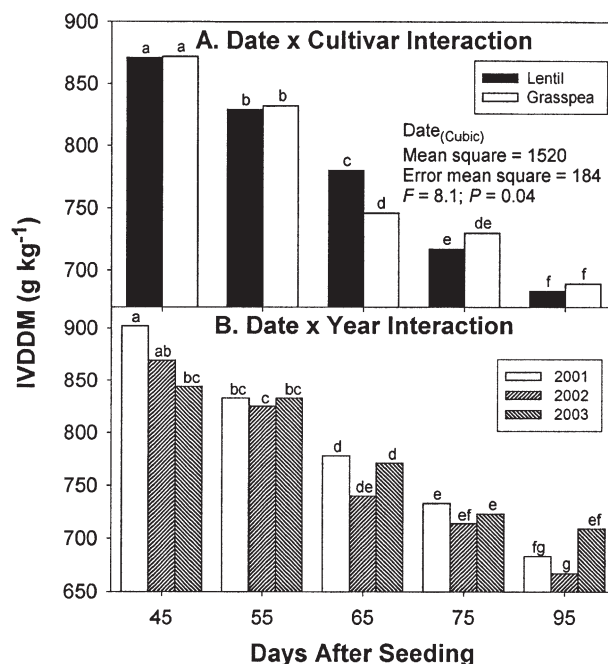
However, grasspea is grown as a source of N in rotation with rice (*Oryza sativa* L.) across Asia, so it apparently is productive under wet conditions (Campbell, 1997). Studies in tropical India and Bangladesh have reported high levels of production by grasspea in different agronomic systems (Gowda and Kaul, 1982; Kaul et al., 1986; Rathod, 1989). It can be surmised that both cultivars should produce greater amounts of biomass under wetter growing conditions.

Greater amounts of precipitation in the southern Great Plains do not help fill the spring period of forage deficit. Regardless of growing conditions, wheat will still begin senescence in May (Krenzer, 2000), and warm-season forages will not produce large amounts of biomass until warmer weather arrives (Northup, 2003). Even wet years will have a forage deficit in May and early June.

The best time to begin grazing grasspea appears to be between 55 and 65 DAS (approximately 10–15 May). If grazing were started early in the exponential phase of growth (55–65 DAS), grasspea could have supplied cattle (*Bos* spp.) with $2950 \pm 700$ kg ha$^{-1}$ forage during this study. This level of production would support 270 to 385 grazing days per ha$^{-1}$ for 300 to 400 kg cattle, assuming they grazed all available forage. Given that an additional $2750 \pm 150$ kg ha$^{-1}$ forage was produced by the end of the growing season, forage production could probably stay ahead of livestock requirements and provide cattle the opportunity to select diets without constraint on total intake or diet quality (Stuth, 1991) for 30 to 40 d. In contrast, the most effective date to initiate grazing for lentil appears later than grasspea (65–75 DAS, 20–30 May), and fewer grazing days would have been available. Further, this starting date would not fill the spring (May) forage gap as effectively as grasspea.

There are no prior reports on the effects of either cultivar on N concentrations in grazing systems of the southern Great Plains. However, values for N cycling and retention in winter wheat with high N concentrations are available that can give some indication of the impact of grasspea or lentil on the N cycle. Phillips et al. (1995) reported that growing cattle grazing winter wheat with 2.2 to 2.9% N excreted $69 \pm 11\%$ of total consumed N as urine ($42 \pm 12\%$) or feces ($27 \pm 2\%$). Other studies (Wilkinson and Lowrey, 1973; Floate, 1981) noted similar N concentrations in urine and feces. Using these values, we can estimate the potential input of N in grasspea or lentil standing crop to a paddock and N available for a following crop of winter wheat in a two-forage rotation. Grasspea used as forage (assuming full utilization of aboveground standing crop) would provide 115 kg N ha$^{-1}$ in feces and urine to the soil in readily decomposable forms. On the basis of the percentages of Phillips et al. (1995) for wheat with high N concentrations, roughly 45 and 71 kg ha$^{-1}$ of N would be excreted in urine and feces, respectively. Nitrogen in urine tends to be highly labile and susceptible to loss in runoff water and by volatilization (Wilkinson and Lowrey, 1973), so much of this N may not be retained. However, grasspea would still input enough N in feces to meet 30 to 40% of N requirements for forage wheat in the following year. In contrast, lentil would have produced an average annual input of only 14 and 22 kg N ha$^{-1}$ in feces and urine, respectively. These calculations suggest that grasspea could be highly effective as a grazed forage in rotation with other crops.

## CONCLUSIONS

Results suggest that environmental conditions, especially temporal distribution of precipitation, played an important role in the performance of both annual legumes. Biomass production was highest in 2001 and could be attributed to above normal precipitation in May 2001. Alternatively, precipitation during 2002 and 2003 was least during the first half of the study, and end-of-season production was less. Biomass yield of grasspea on the last sampling dates was 2.5 to 3.8 times greater than lentil. Little difference in N concentration or IVDDM was noted between the two cultivars by the later sampling dates. We conclude that grasspea has the potential to provide greater biomass and nutritive value to livestock during the May through June forage deficit period that occurs in the southern Great Plains during years of below-normal rainfall in the spring and early summer.

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